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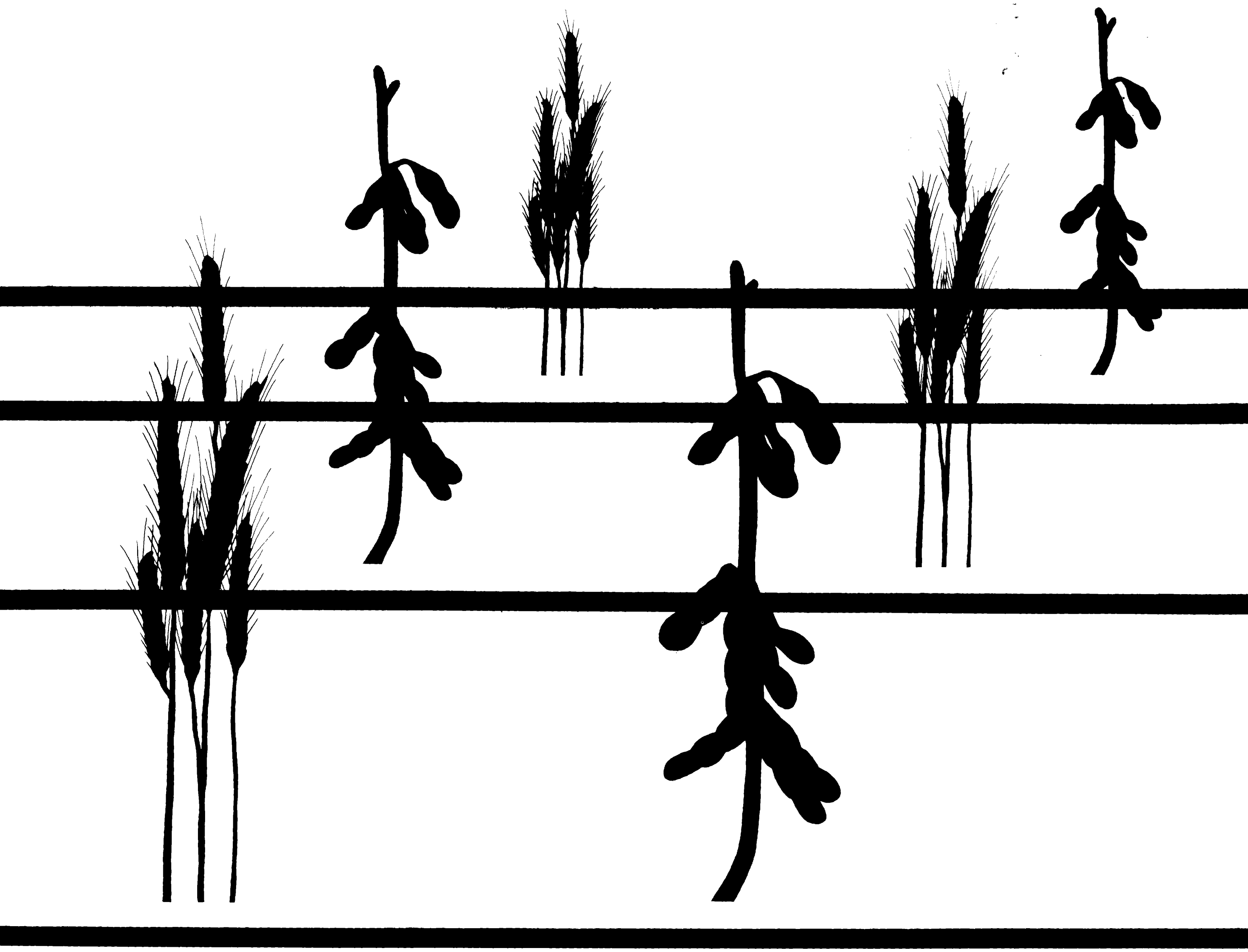
Double-Cropping Wheat and Soybeans in the Southeast

Input Use and Patterns of Adoption

Michele C. Marra
Gerald A. Carlson



Double-Cropping Wheat and Soybeans in the Southeast: Input Use and Patterns of Adoption. By Michele C. Marra and Gerald A. Carlson. Natural Resource Economics Division, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 552.

Abstract

Southeastern farmers have increased their double-cropped wheat and soybean acreage by nearly half since 1970. Double-cropping, the raising of two crops per year in the same field, helps raise producer revenues and reduce total input use, since it encourages conservation tillage by farmers. But double-cropping seems to make soybean yields more variable and has helped to quadruple stockpiles of surplus soft red winter wheat since 1970. This report gives State data for double-cropping and examines the factors that caused the year-to-year expansions and contractions in double-cropped acres since the seventies.

Keywords: Double-cropping, wheat, soybeans, conservation tillage, input use, risk, production under uncertainty, pesticides.

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Contents

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Summary

Farmers in the Southeastern United States now double-crop wheat with soybeans on nearly 30 percent of their soybean acreage, up from less than 20 percent in 1970. And in at least one year (1982), the double-cropped acreage exceeded 40 percent. While double-cropping generally raises returns to farmers, its expansion has not been steady. The yield from the soybean crop tends to be more variable than with single-cropped soybeans; and farmers may forgo planting wheat when relative wheat prices are lower, when variability of wheat revenue is increased, or when the additional costs for double-cropping are higher.

Double-cropping refers to the practice of farmers' planting wheat after harvesting a soybean crop, then harvesting the wheat in the spring in time to plant a new soybean crop. Thus, farmers get two crops from the same field instead of only one. This report examines the factors that caused the expansion and contraction of double-cropped acreage in the midseventies and early eighties, as well as changes in input use.

The expansion of double-cropping in the seventies and eighties has increased the Southeast's and the Nation's production of soft red winter wheat, a crop in surplus since 1970. By 1984, U.S. stockpiles of soft red winter wheat reached 80 million bushels compared with less than 20 million in 1970.

Other major findings include:

- Farmers' decisions about the proportion of soybean land allocated to double-cropping are more sensitive to changes in wheat revenue than in soybean revenue.

- Double-cropping is usually associated with conservation tillage, which takes less time than conventional tillage.

- The relative level of pesticide use on double-cropped soybean acres compared with that on single-cropped soybean acres declined between 1978 and 1982.

- The expansion of double-cropped acreage in the past 10 years doubled the Southeast's share of total U.S. wheat production to over 10 percent.

The methods of analysis used in the study are statistical comparisons of means and proportions, linear regression, and nonlinear regression. The economic information analyzed includes State-level output and price data for wheat and soybeans, U.S. wheat production data, and individual farm data from USDA's 1978 and 1982 Soybean Cost of Production Survey.

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Introduction

Double-cropping small grains and grain sorghum for commercial production began in the Southern United States before World War II. More recently, soybeans following small grain as a double-cropped system has gained in popularity among Southeastern U.S. farmers.

"Small grain followed by soybeans is the agronomic multicropping system most widely grown in the southeast U.S., and probably in the world" (*2*, p. 2)[1] Figure 1 and table 1 show the double-cropping patterns in the Southeast over the last 15 years. There are differences in the rates of increase both among States and between groups of States that share common environmental factors. (See maps, in the middle of this publication, for geographical distribution of double-cropping from producers sampled in the 1978 and 1982 USDA Soybean Cost of Production Surveys. These surveys are described in more detail later in this report.) There also have been periods — midseventies and early eighties — when soybean double-cropping has declined (fig. 1). Such declines are unusual for a new, potentially more profitable technology, and raise questions about which economic and biological factors are most important in explaining double-cropping patterns.

Double-cropping can influence the financial condition of soybean producers in the Southeast. Further, if the Southeast becomes a major wheat-producing region, the financial condition of producers in other wheat-producing regions may be affected. Double-cropping also implies potential changes in the use of inputs such as pesticides and tillage practices. These changes may impose environmental costs or benefits that reach beyond the agricultural sector. An understanding of the major factors influencing the growth patterns of this new technology and the likely input-use changes this growth implies will be beneficial to policymakers and others interested in the welfare of U.S. agriculture and in the optimal use of our environmental resources.

This study presents an analysis of the economic factors and regional and farm characteristics associated with double-cropping as a production practice as well as important input-use changes associated with double-cropping. Increased double-cropping may be affected by other new technologies, varieties, pesticides, and herbicides, and may, in turn, affect the adoption of such technologies as conservation tillage and plant growth regulators. Crop statistics on double-cropping are limited. This report organizes most of the available data and suggests areas for data expansion.

Double-cropping wheat and soybeans begins with preparation of the seedbed using conventional tillage methods in the fall for planting soft red winter wheat. Conventional tillage includes moldboard plowing followed by disking and, possibly, harrowing. After wheat harvest in late spring or early summer (mid-to-late June in the Southeast and as late as July 10 in the southern Corn Belt, soybeans are planted with either conventional or conservation tillage methods (*9*).

Figure 1
Soybean acreage double-cropped in the Southeast

Average of Alabama, Arkansas, Georgia, Kentucky, North Carolina, South Carolina, Tennessee, and Virginia. 1972–73 data not available.
Source: Unpublished data, U.S. Dept. of Agriculture, Crop Reporting Board.

The authors are Assistant Professor, University of Maine at Orono and Professor, North Carolina State University. This work was accomplished under Research Agreement No. 58-319V-4-00232, NRED/ERS/USDA.

[1]Italicized numbers in parentheses cite references listed at the end of this report.

Table 1—Soybean acreage double-cropped in Southeastern States[1]

Year	Alabama	Arkansas	Georgia	Kentucky	North Carolina	South Carolina	Tennessee	Virginia	U.S.
					Percent				
1968	11.9	14.0	39.8	2.0	12.3	15.6	17.6	23.1	6.5
1969	23.9	7.0	27.5	6.6	12.7	18.2	7.3	33.7	4.5
1970	29.9	4.4	23.5	4.6	18.2	22.9	9.1	30.6	4.0
1971	22.5	3.0	40.1	9.8	17.7	22.8	8.8	36.7	4.6
1974	20.0	9.3	29.4	20.5	21.5	21.3	15.9	48.2	7.3
1975	14.3	12.3	17.5	25.7	17.4	16.3	8.8	40.5	11.0
1976	9.1	19.5	25.0	26.2	16.8	19.6	16.8	47.6	9.1
1977	7.3	15.7	18.9	14.5	18.9	13.4	12.5	47.4	7.3
1978	10.8	8.9	26.1	7.3	10.9	14.9	3.7	25.2	5.1
1979	12.3	11.2	22.7	11.6	11.0	16.6	7.6	27.9	5.8
1980	14.8	18.1	38.4	17.6	24.1	15.1	23.8	37.2	9.1
1981	26.3	33.0	51.8	35.1	34.6	36.4	34.0	50.8	14.7
1982	37.1	35.1	58.5	33.0	36.7	44.1	31.8	43.3	16.2
1983[2]	11.8	27.0	32.1	28.8	24.6	25.7	21.6	43.6	12.0
1984	21.0	25.0	31.0	34.0	32.0	32.0	27.0	38.0	11.0

[1]Data for 1972 and 1973 are unavailable. Louisiana and Mississippi are excluded from this table and from the section titled "Double Cropping and U.S. Wheat Production." They are, however, included in the sections on input use implications, since complete data for these States are available in the Cost of Production Surveys.
[2]1983 percentages are adjusted for the Payment-in-Kind (PIK) program by using the average of the past 3 years' acreage as the base acreage.
Source: (*21*).

Conservation tillage methods disturb the soil surface less than conventional tillage in planting the crop.

> "The common element running through . . . various definitions of conservation tillage is the presence of crop residue on the soil surface to reduce water and wind erosion and, in the Great Plains, to increase soil moisture. The amount of crop residue may vary widely, but it must be enough to reduce erosion significantly in comparison with tillage systems that bury or remove the residue." (*1*, p. 1).

For this study, we followed the definition of conservation tillage put forth by the southeastern agricultural engineers: If no more than 30 percent of the soil surface was disturbed, then we assumed conservation tillage was practiced.

Conservation tillage planting for soybeans involves using a fluted coulter-planter and, possibly, a subsoiler attachment, but no moldboard plow. The coulter cuts through the residue left on the soil surface in a band only wide enough to plant the seeds with the planter. Previous crop residue is left on the soil surface to act as a mulch to trap soil moisture and to help control wind and water erosion. Conservation tillage may also act to control the soybean cyst nematode, the major disease carrier for U.S. soybeans (7). With conservation tillage, farmers must use postemergence herbicides to control weeds, whereas with conventional tillage, preplant herbicides and between-row cultivation can be used, along with postemergence herbicides. Continual use of conservation tillage may also result in excessive soil compaction.

In double-cropping, the growing season for the soybeans is shortened because of the overlap in harvesting the first crop and planting the second. Conservation tillage, therefore, offers an advantage in that it is quicker than conventional tillage (fig. 2). Indeed, wheat may be harvested in the morning and soybeans planted in the afternoon of the same day in the same field with conservation tillage. Farmers with the labor and equipment to operate two crews, can be combining wheat in some fields while planting beans in others. This practice can give the soybeans an extra week or two of growing time over conventionally planted double-cropped beans (*15*). "Generally, yields of mid-season and full-season soybean cultivars begin to drop when planted after mid-June" (*9*, p. 48).

The yield of the late-planted, double-cropped beans was about 8 percent less than the yield of full-season beans (table 2).

Soybeans depend upon day length for flowering. When double-cropping, therefore, farmers ought to select short-season, medium-to-late-maturing varieties to provide adequate plant growth before flowering. Otherwise, the beans may start to flower soon after emergence and produce significantly lower yields. "Medium maturing varieties include Centennial, Coker 156, and Davis, while later maturing varieties include Bragg, Coker 237, GaSoy 17 and Ransom" (*8*, p. 5). Bragg was

Figure 2

Typical growing seasons for various soybean cropping systems and tillage methods in the Southeast

1. Full-season, single-cropped soybeans.

PB (May) — HB (November)

J F M A M J J A S O N D

Growing season

2. Double-cropped, conventionally tilled soybeans.

HW (June) PB (July) — HB (November) PW (December)

J F M A M J J A S O N D

Growing season

3. Double-cropped, no-till soybeans.

HW PB (June) — HB (November) PW (December)

J F M A M J J A S O N D

Growing season

PB = Plant beans HB = Harvest beans
PW = Plant wheat HW = Harvest wheat
Source: (11)

Table 2—Average nonirrigated soybean yield, by State and cropping practice, 1982

State	Single-cropping only	Both[1] Single-cropped acres	Both[1] Double-cropped acres	Double-cropping only
		Bushels/acre		
Alabama	25.5	28.5	23.0	25.8
Arkansas	18.1	23.1	20.1	27.6
Georgia	30.7	27.2	23.3	24.0
Louisiana	26.0	32.2	27.0	—
Mississippi	30.3	25.0	20.8	—
North Carolina	28.0	27.3	26.6	24.0
South Carolina	21.4	24.5	22.2	24.3
Tennessee	26.2	30.7	26.3	34.0
Virginia	28.7	36.7	34.4	25.5
Southeast	26.1	27.4	24.1	25.8

— = too few observations to be reliable.

[1]This yield comparison is for the same producer, so locational and management differences are minimized.

Source: (19).

introduced in 1984 and the others were introduced in the mid- to late-seventies.[2]

The introduction of higher yielding wheat varieties also has had a positive effect upon double-cropping in the Southeast. In the early sixties, a yield of 50 bushels per acre was expected, whereas 80 bushels per acre is the current norm in research trials in some areas of the Southeast.[3] In the late sixties, Blue Boy and Coker 68-15, higher yielding varieties, were introduced but both were found to be susceptible to a new strain of mildew. By 1973, higher yielding mildew-resistant varieties, such as Arthur, were developed. In the last few years, even higher yielding resistant varieties have been made available for the Southeast. These include the early season varieties such as McNair 1003, Coker 747, and Roy.

Recent developments in herbicides have also contributed to successful double-cropping in the Southeast. Because of the increased effectiveness of post-emergence herbicides, the opportunity for successful reduced tillage practices has increased. This opportunity has, in turn, potentially increased the available growing season for double-cropped soybeans throughout the Southeast and made double-cropping feasible as far north as southern Illinois and Ohio (*9*).

Double-cropped soybeans in the Southeast may have higher infestations of insect pests than single-cropped soybeans (*21, 14*). For the same expenditure on insecticides in the two systems, therefore, yields would be expected to be less in the double-cropped system.

Double-cropping has advantages and disadvantages in terms of the risk associated with weed infestations. The presence of the winter wheat crop may inhibit weed growth in the soybean crop. "Dense small grain stands can . . . reduce the potential weed infestations and weed size at planting time for double cropped . . . soybeans" (*10*, p. 9). Herbicides applied at soybean planting may, therefore, be more effective. Where conservation tillage is used, however, the weed populations that do develop must be controlled with postemergence herbicides that may have more variable results than preplant-incorporated treatments or between-row cultivation. In conventionally tilled, double-cropped soybeans, less risky methods can be used to control the weeds but at the cost of shortening the growing season for the soybeans. In both cases, beans planted in narrow rows will provide quicker shading out of the weeds. Recommended row width for late-planted beans is 15-20 inches to give quick shade (*10*).

Available moisture at soybean planting and emergence has a substantial effect on subsequent yields. If moisture is below normal, soybean yields will suffer (*4*). Conservation tillage reduces the risk of inadequate soil moisture by using wheat straw as a mulch. Single-cropped beans normally are planted in late April and May when soil moisture is likely to be adequate in the Southeast.

In a double-cropped system, wheat harvest and soybean planting do not compete for the capital and labor requirements for planting most other crops. There may, therefore, be savings to the farmer in terms of total capital and labor that must be available during the

[2]March 17, 1983, correspondence from E. James Dunphy, Associate Professor of Crop Science, North Carolina State University at Raleigh.

[3]March 19, 1983, correspondence from Charles Murphy, Professor of Crop Science, North Carolina State University at Raleigh.

season. A farmer can spread managerial talent, hired labor, and machinery more smoothly over the growing season by partially double-cropping.

In sum, there is more risk of reduced yields with double-cropped beans. That risk must be balanced against the expected increase in net revenue from the two crops as the farmer decides whether to double-crop. Double-cropping requires specialized management skills, not necessarily required for conventionally tilled soybeans, and raises the farmer's exposure to risk. Management of that risk is crucial for successful double-cropping (*9*). No-tillage planting techniques may eliminate some of the risk.

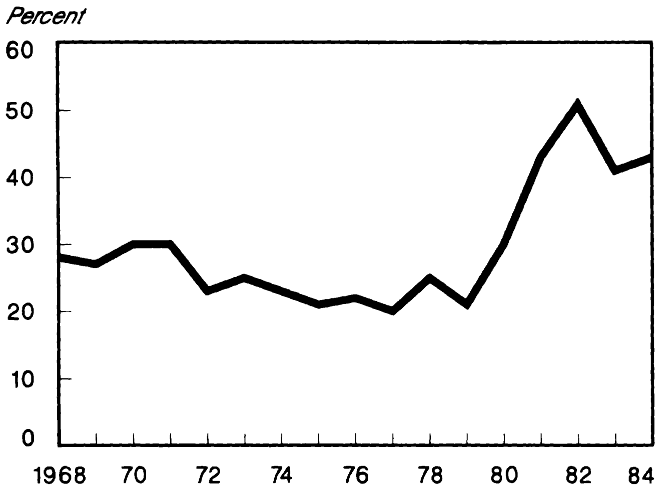
Double-Cropping and U.S. Wheat Production

The increased feasibility of double-cropping wheat and soybeans has increased the relative importance of southeastern wheat production (fig. 3). In the early seventies, the Southeast produced 25 percent of total U.S. soft winter wheat, with the remainder produced mainly in the eastern Corn Belt.

By the early eighties, however, this share had risen to more than 40 percent. Over the same period, U.S. carryover stocks for soft red winter wheat also rose (fig. 4). In the early seventies, carryover stocks averaged 15-20 million bushels while the carryover for the early eighties averaged 55-65 million bushels.

The proportion of soft red winter wheat in total U.S. wheat production remained relatively constant until the early eighties, when it rose sharply (table 3). With the expansion of double-cropping, the Southeast's share of U.S. wheat production has doubled and now represents over 10 percent of total wheat production.

Figure 3
Southeast's share of total U.S. soft red winter wheat production



With the current concern over the costs of carryover stocks and the debate about production policies for wheat and other food and feed grains, it becomes increasingly important to analyze the factors causing this recent trend in wheat production in the Southeast.

A final policy concern is environmental damage from double-cropping. Especially in the northern areas of the Southeast, double-cropping may imply use of conservation tillage practices because of the shorter growing seasons. Conservation tillage may, in turn, imply less soil runoff and increased soil productivity (*15*). Conversely, double-cropping may also imply increased pesticide use and associated additional costs. The potential increase in chemical pesticide use as a result of widespread use of conservation tillage practices poses some serious environmental concerns.

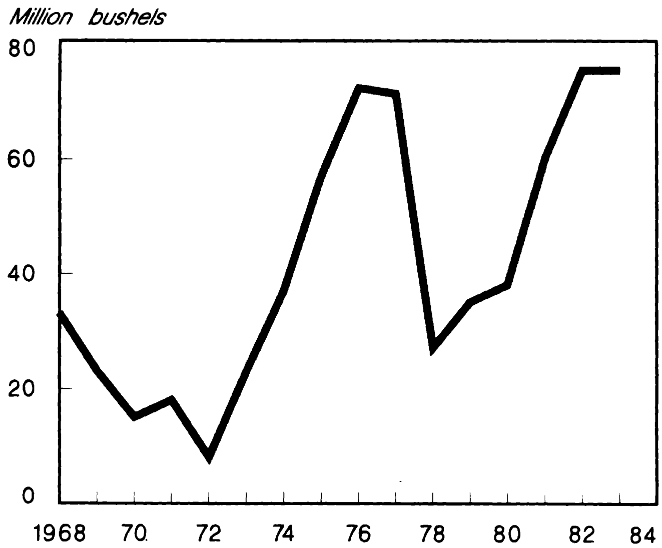
> "On balance, the increased reliance of conservation tillage on pesticides, particularly herbicides, makes it a greater threat to the environment than conventional tillage as far as pesticide damage is concerned . . . The tradeoff between erosion damages and the threat of higher pesticide damages will be crucial to conservation tillage." (*1*, p. 29).

Table 3—Soft red winter wheat as proportion of total U.S. wheat production

	Percent
1950-53	15
1965-69	15
1973-76	13
1980-84	21

Sources: (*5, 20*).

Figure 4
U.S. soft red winter wheat carryover stocks



The Decision to Double-Crop

To understand the factors affecting the pattern of double-cropped soybean acreage, we developed a producer decision model taking into account the costs and returns of each cropping system and the relative riskiness of each (*11*).

Model

We assumed that each producer wishes to maximize the expected utility of profit from the soybean acreage by allocating a portion of that acreage to full-season soybeans and the rest to double-cropped wheat-soybeans. These individual decisions for each year were aggregated to the State level and analyzed using State-level output and price data for 1968-82 for eight States: Alabama, Arkansas, Georgia, Kentucky, North Carolina, South Carolina, Tennessee, and Virginia.

The farmer's decision model is to maximize:

$$EU(\pi) = EU\,[(\alpha P_sB + rP_wW)X + P_sB(1-X) - C(X)]L \qquad (1)$$

with respect to X.

Where:
- $EU(\pi)$ = the expected utility of profit from a farmer's soybean acreage,
- P_sB = the total revenue per acre from the farmer's double-cropped soybeans (α is a parameter capturing the reduction in yield expected from the double-cropped beans, $0<\alpha<1$),
- rP_wW = the total revenue from the farmer's wheat (r is a parameter capturing the opportunity to gain income earlier in the production season and either invest it or defray some operating costs),
- X = the proportion of total soybean acreage double-cropped,
- P_sB = the total revenue per acre from the farmer's full-season soybeans,
- $C(X)$ = the total cost of producing both full-season soybeans and double-cropped wheat-soybeans, and
- L = the farmer's soybean acreage.

This maximization leads to the optimal proportion double-cropped (X^*) as:

$$X^* = [EU'(\pi)X_1 + EU''(\pi)X_2]/[EU'(\pi)X_3 + EU''(\pi)X_4] \qquad (2)$$

Where:
- X^* = the optimal proportion double-cropped,
- $E,','' $ = the expectations operator, the first and second derivatives,
- $X_1 = (\alpha - 1)E(P_sB) - rE(P_wW)$,
- $X_2 = (\alpha - 1)L\ \mathrm{var}(P_sB) - Lr\ \mathrm{cov}(P_sB,P_wW)$,
- $X_3 = -C'$, and
- $X_4 = -(\alpha-1)^2L\ \mathrm{var}\ (P_sB) + r^2L\ \mathrm{var}(P_wW) + [2(\alpha-1)]rL\ \mathrm{cov}(P_sB,P_wW)$.

From (2) the resulting estimating equation is:

$$X^* = b_o + (b_1X_1 + b_2X_2)/(b_3X_3 + b_4X_4) + e \qquad (3)$$

Where:
- b_i = a parameter to be estimated, and
- e = the error term ($E(e) = 0$) that takes into account factors known to decisionmakers but not observable by the authors.

Equation 3 is estimated using nonlinear regression techniques using State-level data. Since X^* is a complex function of the explanatory variables, the parameter estimates are relatively uninteresting and will not be reported here. See (*11*) for more information about estimation techniques. Also, see the appendix for a more detailed description of the modeling process.

Results

Elasticities for 1982 from estimation of the parameters of the model described above and in the appendix are presented in table 4. The elasticities are conventional and can be interpreted as the percentage change in the proportion double-cropped with a 1-percent change in the explanatory variable. Note that the elasticities with respect to the first two moments of wheat return are much larger in absolute magnitude than their soybean revenue counterparts. For the most part, the elasticities have signs consistent with expectations (*11*). The exceptions are the elasticity with respect to additional cost for Georgia and the variance of wheat revenue for Kentucky and Tennessee.

Model predictions were made for the proportion of double-cropped acreage by State in 1983 and 1984. These are presented in table 5 along with the actual proportions for these years. The model predicts well, especially for the States in the mid-South.

To illustrate how this model fares in terms of explaining the variation (from one State to another and from one

Table 4—Elasticities of economic variables from the decision model for 1982

State	Interest rate	E(TR) soybeans	E(TR) wheat	V(TR) soybeans	V(TR) wheat	COV(TR)	Marginal cost
Alabama	0.0511	−0.1687	1.0502	−0.000040	−0.008900	0.0158	−0.8241
Arkansas	−.0011	−.1174	1.2347	−.008400	−.000100	−.0455	−1.4947
Georgia	.1456	−.0390	.3818	−.016300	−.087800	−.2251	1.1709
Kentucky	.0940	−.0183	.6335	−.000007	.000015	.0007	−.6652
North Carolina	−.0994	−.0453	1.2726	.006300	−.023900	−.0230	−.6167
South Carolina	.0832	−.0393	1.0146	−.000900	.016800	.0860	−1.1498
Tennessee	.6590	−.2357	1.3820	.001300	−.001400	.0066	−.1096
Virginia	.0751	−.0139	.2078				

E(TR) = Expected total revenue. V(TR) = Variance of total revenue. COV(TR) = Covariance between total revenue of soybeans and the total revenue of wheat.

Source: (*11*).

Table 5—Comparison of 1983 and 1984 model predictions to actual proportions double-cropped, by State

State	Year	Predicted	Actual
Alabama	1983	0.211	0.118[1]
	1984	.204	.210
Arkansas	1983	.233	.270
	1984	.241	.250
Georgia	1983	.391	.321
	1984	.268	.310
Kentucky	1983	.220	.288
	1984	.248	.340
North Carolina	1983	.214	.246
	1984	.329	.320
South Carolina	1983	.221	.257
	1984	.284	.320
Tennessee	1983	.188	.216
	1984	.264	.270
Virginia	1983	.335	.436
	1984	.440	.380

[1]Actual proportions for 1983 are adjusted for the effects of the Payment-in-Kind program by using the average of the past 3 years' total acreage as a basis for the proportion.

Source: (*11*).

year to another) in the proportion of soybean acreage double-cropped, figures 5, 6, and 7 portray the actual and predicted proportion for Alabama, North Carolina, and Tennessee for 1970-84. At least for this particular application, the model seems to track the wide swings in the proportion across years fairly well. Again, the major factor seems to be the change in the distribution of wheat revenue, with changes in additional cost also an important factor.

The decrease in the proportion double-cropped in the midseventies and eighties was closely linked with falling wheat revenue and increased variability in wheat revenue (*11*). Farmers in the Southeast can be expected to increase double-cropping by about 1 percent for each 1-percent increase in expected wheat revenue (other factors constant).

Effects of Double-Cropping on Input Use

An enumerative survey is taken every 4 years by the U.S. Department of Agriculture to determine the costs of production of the major agricultural products produced within a region of the United States. These surveys are mandated by law to aid agricultural policy. They are conducted on a rotating, regional basis. Surveys were taken in 1978 and 1982 for the Southeast.

The cost of production surveys for 1978 and 1982 contain 453 and 314 responses, respectively, from soybean producers in the Southeast. These responses came from eight States in 1978: Alabama, Arkansas, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee. Responses from Virginia were also included in the survey for 1982. These responses can be categorized by cropping practice according to whether the respondent planted full-season soybeans only, both full-season and double-cropped soybeans, or double-cropped soybeans only. This categorization is interesting because the availability of management skills and capital may influence a farmer's double-cropping decision. By looking at the characteristics of those who planted both full-season and double-cropped soybeans, we can be reasonably sure that differences in management and physical capital do not affect input decisions for the two cropping practices.

The percentage of sample farmers who planted double-cropped soybeans rose from 28 percent in 1978 to 47 percent by 1982 (table 6). This table also shows that many producers use both cropping systems. Said differently, very few farmers are double-cropping on all their soybean acres.

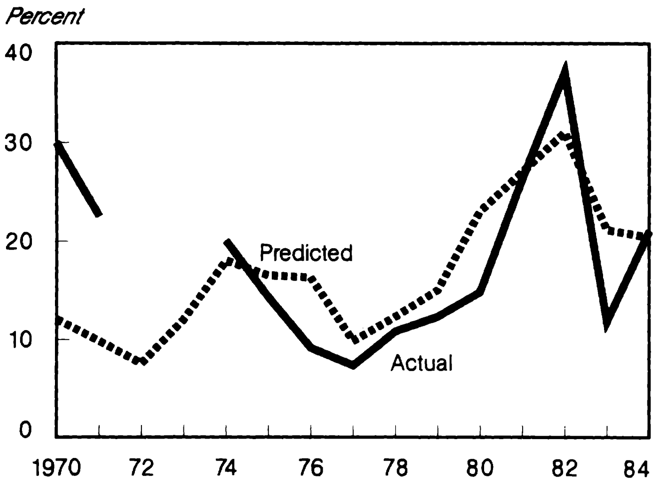
In 1978, 25 percent of the total sample were planting both full-season and double-cropped soybeans on their acreage. By 1982, almost 40 percent of those sampled reported doing both. Consequently, the percentage of southeastern soybean producers planting full-season soybeans exclusively declined from 72 percent in 1978 to only 52 percent in 1982.

Effects on Conservation Tillage

Casual evidence suggests that increased double-cropped acreage in the Southeast may imply increased conservation tillage practices as well. The survey responses may bear out that point. The total number of times a producer passes over the fields from seedbed preparation before soybean planting through soybean harvest can be calculated. Also, the types of machinery used on each pass is included in the survey responses. Tables 7 and 8 present the average number of passes over the field by State and cropping practice for 1978 and 1982.

One interesting thing about table 8 is that farmers with both single- and double-cropped soybeans reported fewer passes over their double-cropped soybeans than over their full-season soybeans. One reason for such a difference may be management ability and planning. Another reason may be differences in location that cause differences in weather, soil type, weed infestations, insect infestations, and so on. A third reason could be the use of conservation tillage practices. With conservation tillage or no-till, there is less seedbed preparation, so there is usually a savings of machine operation compared with conventional tillage. If the producer is using conservation tillage practices, then plowing

Figure 5
Alabama: Actual and predicted soybean acreage double-cropped



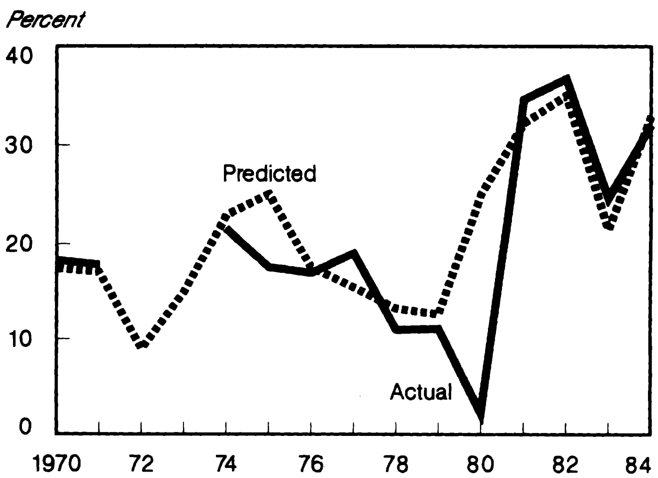
1972-73 data not available.
Source: (11)

Table 6—Respondents to soybean cost of production surveys, by State and cropping practice

State	Single-cropping only 1978	Single-cropping only 1982	Both single- and double-cropping 1978	Both single- and double-cropping 1982	Double-cropping only 1978	Double-cropping only 1982
	Number					
Alabama	47	20	9	10	3	3
Arkansas	29	25	28	19	5	8
Georgia	40	26	12	32	0	7
Louisiana	55	29	1	4	0	1
Mississippi	53	20	7	13	0	0
North Carolina	37	14	15	8	5	4
South Carolina	39	11	22	15	1	2
Tennessee	27	13	17	10	1	1
Virginia	0	3	0	6	0	1
Southeast	327	170	111	117	15	27
	Percent					
Percent of total survey respondents	72	52	25	39	3	8

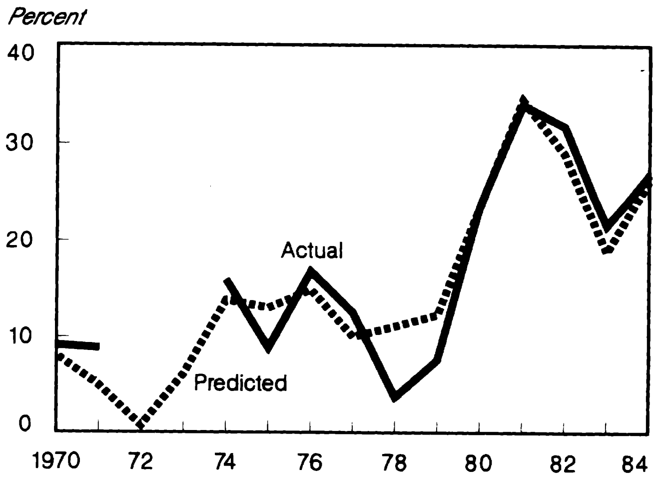
Source: (18, 19).

Figure 6
North Carolina: Actual and predicted soybean acreage double-cropped



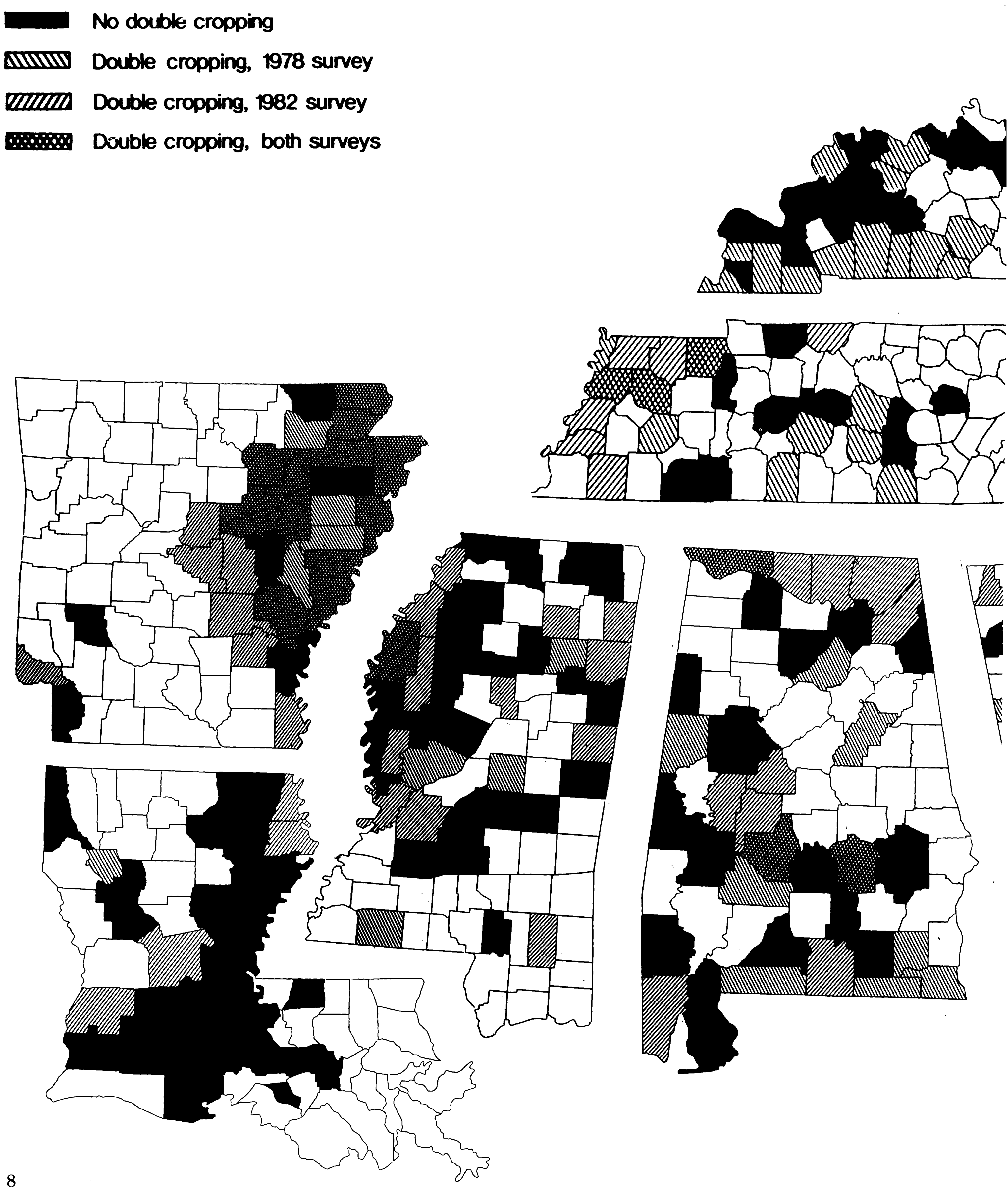
1972-73 data not available.
Source: (11)

Figure 7
Tennessee: Actual and predicted soybean acreage double-cropped



1972-73 data not available.
Source: (11).

Southeast counties double-cropping wheat and soybeans



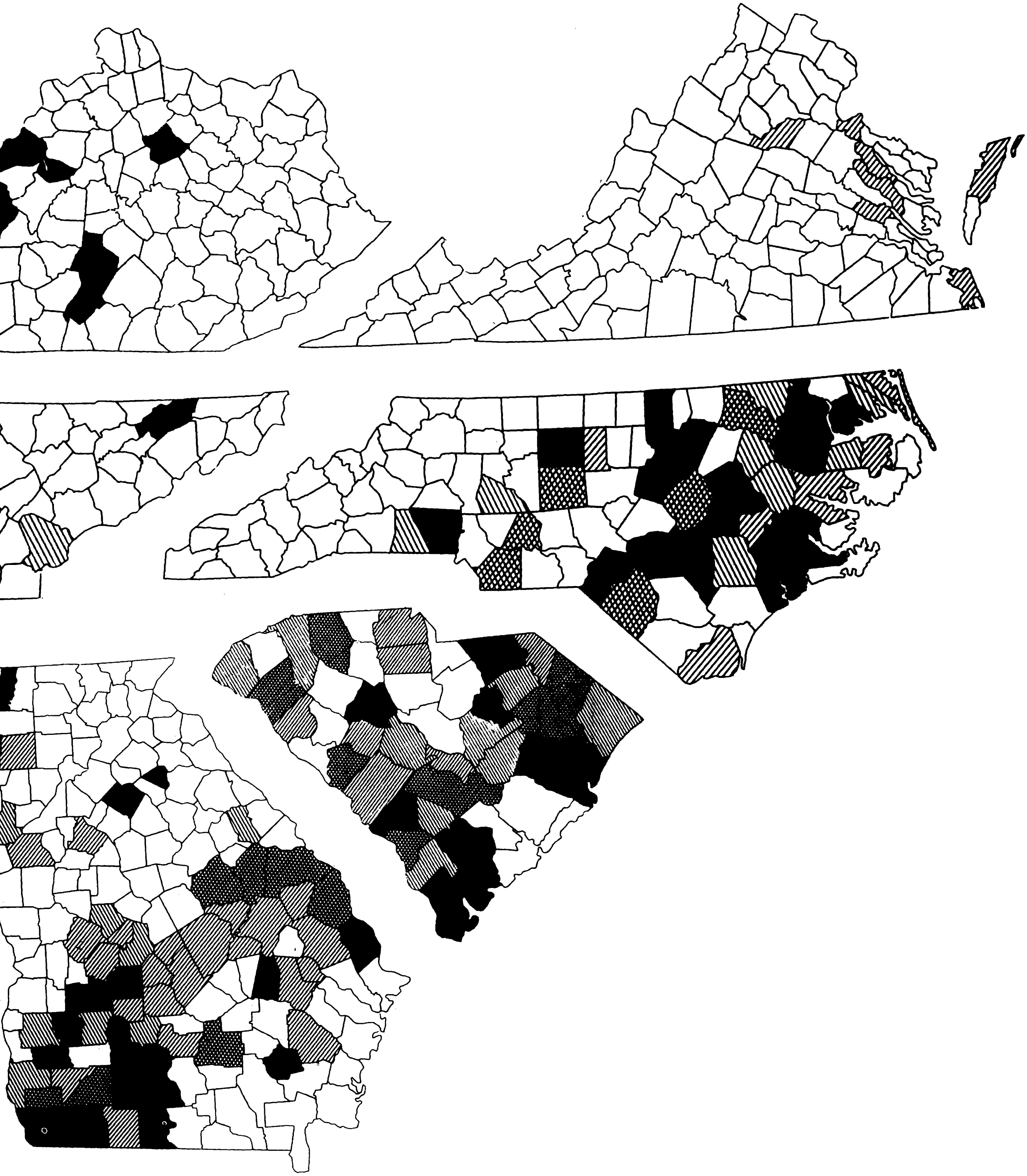


Table 7—Passes over the field, by State and cropping practice, 1978

State	Single-cropping only	Double-cropped acres[1]	Double-cropping only
		Number	
Alabama	9.81	7.89	8.33
Arkansas	10.14	7.82	—
Georgia	7.98	7.92	7.40
Louisiana	11.33	—	—
Mississippi	10.40	9.57	—
North Carolina	7.95	6.87	5.20
South Carolina	7.79	7.23	—
Tennessee	8.15	6.82	—
Southeast	9.38	7.57	6.80

— = too few observations to be reliable.

[1]In the 1978 survey, enumerators were instructed to ask only about practices on double-cropped acres if the respondent reported both systems.

Source: (*18*).

Table 8—Passes over the field, by State and cropping practice, 1982

State	Single-cropping only	Both: Single-cropped acres	Both: Double-cropped acres	Double-cropping only
		Number		
Alabama	7.15	9.80	6.20	8.67
Arkansas	7.52	9.52	7.31	7.25
Georgia	5.65	7.34	6.53	4.00
Louisiana	10.34	11.25	11.00	5.00
Mississippi	10.45	9.92	6.23	0
North Carolina	5.86	7.12	5.25	5.50
South Carolina	5.27	8.67	6.33	7.00
Tennessee	8.69	9.00	5.80	3.00
Virginia	7.00	6.50	3.83	5.00
Southeast	7.66	8.58	6.43	5.96

Source: (*19*).

(except for chisel plows) and disking will probably be eliminated, thus reducing the total number of times the producer passes over the fields during the soybean production period. Fewer passes over a field means less diesel fuel use and longer machinery life. It also saves scarce labor resources during planting when labor is in high demand. When considering farmers who planted both full-season and double-cropped soybeans, we may be safe in assuming that the same management skill is applied in both systems and that the two systems share essentially the same locational characteristics, although there may be some incentive to allocate the double-cropped acreage to the land that is most productive and has less weed problem. We can be fairly confident that the reduction in passes over the field is, at least in part, a result of the conservation tillage practices that save time for the double-cropping operation.

Table 9 presents the results of a statistical test of the difference of two means. This test is to determine whether the observed average reduction in passes over the field for the double-cropped acres is statistically significant compared with the average passes over the field for the full-season soybeans where the respondents planted both. For the entire Southeast, the number of passes over the field was significantly lower with double-cropping. This exact test cannot be performed for the 1978 responses because the information on the number of passes over the field on the single-cropped acreage for those who did both is not available. The mean difference between passes over the field for those who planted single-crop soybeans only and those who only double-cropped in 1978 is 5.23, which is statistically significant at the 5-percent level of significance. This test is not as powerful as the 1982 tests because it is not possible to eliminate the effects of differences among producers. It does, however, provide further evidence that double-cropping reduces the average number of passes over the field, thus providing some saving in fuel and labor, and prolonging the economic usefulness of equipment.

To obtain further information on the use of conservation tillage practices from the survey, we attempted to deduce the type of tillage practice from the list of equipment used on the soybean acreage. The section on field operations in the surveys lists type of equipment used in the field operation. These equipment categories come from a separate list that accompanies the surveys, and the respondent is asked to choose the equipment code that most closely matches the type of equipment used in each field operation. First, we assumed that the producer *did not* use conservation tillage practices if any of the following machinery types were used on the soybean acreage during the 1978 production year:

1. Regular moldboard plow
2. Two-way moldboard plow
3. Disk plow
4. Moldboard-packer-drill
5. Plowing tandem disk
6. Light duty offset disk
7. Offset disk
8. Heavy duty offset disk
9. One-way disk tiller
10. Landall, do-all (disk, shovels, reel, and spikes).

In 1982, the moldboard-packer-drill and the offset disk were omitted from the list of machinery that accompanied the survey, so we adjusted our criteria accordingly. These pieces of equipment from the list supplied are assumed to remove no more than 30 percent of the crop residue from the soil surface. An alternative method of detecting conservation tillage practices from equipment use is presented also as a check on the first criterion.

There seems to have been little conservation tillage practiced in 1978 on soybeans and comparisons between cropping practices have little meaning, although there was over twice as much conservation tillage on the double-cropped acres of those who did both compared with those who only single-cropped for the entire region (table 10). By 1982, the amount of conservation tillage had increased dramatically. Caution should be used in interpreting these results, however, because the way in which the implement is used, the soil type, the weather conditions, and the specific design of the implement may affect whether the method is conservation or conventional tillage.

Conservation tillage is expanding among soybean producers. In 1978, only 4 percent of those sampled reported using conservation tillage practices. In 1982, 55 percent reported using conservation tillage. This increase was larger for those who also double-cropped. In 1978, 5 percent of those who did both reported using conservation tillage on their double-cropped acres. By 1982, that percentage had risen to 69 percent. Table 11 presents some statistical comparisons of the difference in the proportion of respondents using conservation tillage by cropping practice. In 1978, the difference between the proportion of those who only single-cropped and those who did both on their double-cropped acres is not statistically significant at the 5-percent level. The same comparison in 1982 is statistically significant. Also in 1982 the same producers showed a significant increase in conservation tillage on their double-cropped acres compared with their single-cropped acres.

Since there are so many variations on the equipment listed, and the use of a certain piece of tillage equipment only implies that the producer did or did not use conservation tillage, we used an alternate method to deduce the tillage practice as a check on the first method. We followed Rahm and Huffman in assuming that the use of a moldboard plow implies conventional tillage practices (*16*). We included the disk plow as well in this criterion on the advice of agricultural engineers. The disk plow is said to disturb the soil surface at least as much as the moldboard plow. Table 12 presents the results of the check criterion for 1982. The results are similar for 1978.

Although the proportions derived from the check criterion are higher than those from the first method, the qualitative comparisons are essentially the same. The only differences are for those who did both in Mississippi and South Carolina. For these two States, the proportions for single-cropped acres are lower than for double-cropped acres by the first criterion, while by the second criterion they are equal.

Effects on Pesticide Use

One of the tradeoffs in double-cropped acreage is the benefit of increased soil conservation versus the environ-

Table 9—Tests of the mean difference in passes over the field, by operators with both single- and double-cropped soybeans

State	Test statistic(t)	Rejection region(5%)[1]
Alabama	2.216	t>2.101
Arkansas	2.603	t>2.093
Georgia	2.511	t>1.960
Louisiana	1.152	t>2.776
Mississippi	6.609	t>2.160
North Carolina	2.958	t>2.306
South Carolina	1.563	t>2.131
Tennessee	3.404	t>2.228
Virginia	1.715	t>2.447
Southeast	5.489	t>1.960

[1]If the test statistic (t) is greater than the rejection region, then we can be 95-percent confident that the passes over the field for the double-cropped soybeans are fewer than the passes over the field for the full-season soybeans. In Louisiana and Virginia, the small number of respondents may make this test invalid.

Table 10—Use of conservation tillage practices, by State and cropping practice, 1978 and 1982[1]

State	Single-cropping only		Both: Single-cropped acres	Both: Double-cropped acres		Double-cropping only	
	1978	1982	1982	1978	1982	1978	1982
	Percent of respondents						
Alabama	4	20	70	22	50	0	0
Arkansas	0	52	58	8	47	0	25
Georgia	0	58	82	0	66	—	100
Louisiana	0	31	75	0	75	—	0
Mississippi	8	55	54	0	31	—	—
North Carolina	0	50	75	7	50	0	75
South Carolina	0	55	67	5	40	0	0
Tennessee	4	38	50	0	10	0	100
Virginia	—	0	100	—	50	—	100
Southeast	2	45	69	5	48	0	52

— = no respondents in that category.

[1]Conservation tillage defined as not using certain equipment; see text.

Sources: (*18, 19*).

Table 11—Tests of differences in proportion of respondents using conservation tillage for selected cropping system comparisons

Comparison[1]	Difference in proportion	Test statistic(t)	Rejection region
	Percentage points		
1978 single-cropped vs 1978 both on double-cropped acres	0.03	1.32	t>1.96
1982 single-cropped vs 1982 both on double-cropped acres	.24	4.19	t>1.96
1982 both on single-cropped acres vs 1982 both on double-cropped acres	.21	3.40	t>1.96

[1]Both = those respondents who reported both single- and double-cropped acres.

mental costs of increased use of chemical pesticides. The environmental impact of chemical pesticides is widely documented; some pests become genetically resistant to certain pesticides, for example, and pathologists may record a higher frequency of certain diseases in humans. Expenditures on chemical pesticides for each producer and each cropping practice is reported in both the 1978 and 1982 cost of production surveys. From this information we can quantify the relationship between the trend in double-cropping and the use of pesticides. The questions we can begin to answer are:

1. Are there significantly larger expenditures on chemical pesticides on double-cropped soybeans compared with full-season soybeans?
2. If there is a difference, does the difference change over time?

Table 12—Use of conservation tillage practices, by State and cropping practice, 1982[1]

State	Single-cropping only	Both: Single-cropped acres	Both: Double-cropped acres	Double-cropping only
	Percent of respondents			
Alabama	70	60	80	33
Arkansas	84	89	95	88
Georgia	73	81	97	100
Louisiana	62	100	100	0
Mississippi	95	100	100	0
North Carolina	57	75	100	100
South Carolina	72	93	93	100
Tennessee	85	70	90	100
Virginia	0	83	100	100
Southeast	74	84	95	85

[1]Conservation tillage defined as not using disk or moldboard plow.
Source: (*19*).

There is direct information from the cost of production surveys on pesticide expenditures. These expenditures are for herbicides, insecticides, nematocides, fungicides, and other. They include all cash outlays except application costs for self-applied materials. The categories and included costs are consistent across years, so direct comparisons can be made. To remove the effect of inflation over time, all expenditures are reported in 1977 dollars.

Table 13 contains information on total pesticide expenditures per acre for 1978 and 1982. For 1978, the regional averages indicate that expenditures on pesticides were about 25 percent higher on double-cropped acres. By 1982, however, pesticide expenditures on double-cropped acreage declined relative to expenditures on single-cropped acreage.

Table 14 presents the results of analysis to test if the differences in expenditures between cropping practices and across time are statistically significant. Since the 1978 survey questionnaire eliminated responses for the single-cropped acreage of those who did both, the comparison across time is between only single-cropped acreage and the double-cropped acreage for those who did both. This comparison should, therefore, be viewed with some caution since the level of management skill cannot be held constant across cropping practices. For 1982, the comparison between the single- and double-cropped per acre pesticide expenditures for those who did both is not statistically significant.

Expenditures on pesticides were significantly higher on double-cropped acres for those who did both compared with expenditures for those who only single-cropped in 1978 but not in 1982. This seems to indicate that the

Table 13—Pesticide expenditures, by State and cropping practice, 1978 and 1982

State	Single-cropping only 1978	Single-cropping only 1982	Both: Single-cropped acres 1982	Both: Double-cropped acres 1978	Both: Double-cropped acres 1982	Double-cropping only 1978	Double-cropping only 1982
	Dollars per acre[1]						
Alabama	11.76[2]	10.89	15.22	15.36	9.39	6.18	5.95
Arkansas	8.33	6.57	12.87	8.61	10.19	—	4.94
Georgia	12.78	15.28	16.01	12.38	17.98	22.89	17.31
Louisiana	19.54	17.88	20.39	7.82	22.01	—	14.04
Mississippi	4.81	10.73	5.70	3.90	6.61	—	—
North Carolina	11.78	9.57	12.17	18.12	11.17	11.49	11.27
South Carolina	10.21	7.84	11.64	23.31	13.02	—	12.30
Tennessee	10.38	11.26	11.68	14.51	11.72	—	16.77
Virginia	—	7.23	12.32	—	12.94	—	16.57
Southeast	11.51	11.50	13.08	14.36	12.96	12.69	10.95

— = Too few observations for a reliable estimate.
[1]Excludes application costs for self-applied.
[2]All expenditures reported in 1977 dollars.
Source: (*18, 19*).

Table 14—Statistical comparison of the difference in mean pesticide expenditures per acre over time and by cropping practice

Pesticide expenditure comparison	Test statistic(t)	Rejection region
1978 single-cropped vs 1978 double-cropped (both)[1]	2.100	t>1.96
1978 double-cropped (both) vs 1982 double-cropped (both)	.644	t>1.96
1982 single-cropped vs 1982 double-cropped (both)	.437	t>1.96
1982 single-cropped (both) vs 1982 double-cropped (both)	.012	t>1.96

[1]Both = respondents who reported both single- and double-cropped acres.

tradeoff between the benefits of double-cropping versus the increased external costs of pesticides may be becoming more favorable. It may be that, as producers learn more about the system, they need fewer applications of pesticides. Data from future surveys will prove very helpful in verifying such a trend, which will go far toward allaying fears about increased pesticide damage from increased double-cropped acreage. Consideration must also be given to changes in off-farm damage per dollar of pesticides for the two cropping systems in the above comparisons.

The two most important groups of pesticides for soybeans are herbicides and insecticides. Tables 15 and 16 demonstrate that there is often a difference in the herbicide and insecticide expenditures from one State

Table 15—Herbicide expenditures, by State and cropping practice, 1978 and 1982

	Single-cropping only		Both: Single-cropped acres	Both: Double-cropped acres		Double-cropping only	
State	1978	1982	1982	1978	1982	1978	1982
	Dollars per acre[1]						
Alabama	6.33	8.68	9.90	7.20	8.63	4.32	3.57
Arkansas	6.45	5.20	11.77	7.47	9.35	—	4.63
Georgia	5.69	7.14	7.95	6.19	8.12	10.96	8.66
Louisiana	12.73	13.87	16.86	6.76	16.05	—	8.94
Mississippi	3.49	7.39	4.55	2.38	5.35	—	—
North Carolina	8.05	7.26	10.28	13.40	9.41	11.49	10.71
South Carolina	5.69	9.02	9.79	9.39	10.78	—	7.14
Tennessee	9.45	11.26	11.55	14.33	11.72	—	—
Virginia	—	3.46	12.32	—	10.59	—	—
Southeast	7.26	8.31	9.59	9.21	9.19	8.35	8.08

— = Too few observations for a reliable estimate.
[1]All expenditures reported in 1977 dollars.
Source: (*18, 19*).

Table 16—Insecticide expenditures, by State and cropping practice, 1978 and 1982

	Single-cropping only		Both: Single-cropped acres	Both: Double-cropped acres		Double-cropping only	
State	1978	1982	1982	1978	1982	1978	1982
	Dollars per acre[1]						
Alabama	3.68	1.23	4.92	0.89	1.08	0	2.37
Arkansas	1.60	.27	.54	.15	.74	—	.30
Georgia	6.89	7.83	6.97	5.29	8.77	8.98	8.37
Louisiana	2.71	3.30	2.28	0	4.94	—	—
Mississippi	.95	1.10	.17	0	.28	—	—
North Carolina	2.79	2.29	1.79	4.30	1.76	0	.57
South Carolina	3.49	1.55	1.77	8.02	2.17	—	0
Tennessee	.08	0	.14	0	0	—	—
Virginia	—	0	0	—	0	—	—
Southeast	2.86	2.44	2.87	2.85	3.18	2.99	2.77

— = Too few observations for a reliable estimate.
[1]All expenditures reported in 1977 dollars.
Source: (*18, 19*).

to another in each year. When regional means for both double- and single-cropped acreage on the same farms in 1982 are compared, we see higher levels of insecticides but *lower* levels of herbicides on the double-cropped acreage. Again, more information is needed to determine if the relative reduction in herbicide use on double-cropped areas is a permanent change.

Relationship to Farm Size

Since double-cropping is a management intensive practice and there is usually a limit to the management time available on any farm, we might expect to see a correlation between the size of the total farm operation and the amount of double-cropped acres planted in any one year. In other words, we can see whether the larger or smaller farms tended to adopt this technology early and how the adoption has been proceeding with regard to farm size.

The largest farms were planting only full-season soybeans in 1978, although in five of the eight States, the largest farms were planting both full-season and double-cropped soybeans (table 17). A large number of the relatively smaller farms were planting only double-cropped soybeans. By 1982, the largest farms were planting both soybean types in every State. Also, for every cropping practice, the average size of the farm operation fell significantly between 1978 and 1982 for the regional averages. The decline in average farm size is particularly sharp for those using single-cropping only.

To quantify further the correlation between double-cropping and farm size, we regressed the percent of soybean acres double-cropped on total operated crop acres and total operated crop acres squared in both 1978 and 1982. We expected a negative sign on the quadratic term in both years because, since double-cropped acres require more management than single-cropped acres, the more total cropland operated, the less management time is available for double-cropping. We also expected to observe a decline in the percent double-cropped in the lower ranges of total operated crop acres since small total operated crop acres may indicate limited available management skill for any cropping practice. Since there is no available information on off-farm work, the hypothesis of a smaller farm size being associated with a lower percentage of soybean acres double-cropped because of limited management ability is not testable with these survey data. The total operated crop acres may be a function of off-farm labor opportunities and a small size may not be solely due to limited management ability. The hypothesis of larger total operation causing a decline in the percentage of soybean acres double-cropped is testable with the data described above. The results of these regressions are found in table 18.

In both years, both the linear and quadratic parameter estimates are significant at the 1-percent level of significance and also have the expected signs. In 1978, the total operated crop acres that gives the maximum percent double-cropped is 18,000. In 1982, this acreage drops to 4,660. It seems that there is a limit to the percent double-cropped as farm size increases, but this limit may not be particularly relevant for the average producer. A more complete model of the effect of producer risk, farm size, and limited resource endowments is developed elsewhere (*13*).

Effects of Policy Changes on Double-Cropping

To consider the effect of changes in Government farm programs on double-cropping, we assumed a gradual

Table 17—Average farm size, by State and cropping practice, 1978 and 1982

	Single-cropping only		Both single- and double-cropping		Double-cropping only	
	1978	1982	1978	1982	1978	1982
			Acres			
Alabama	2,233	1,660	2,513	1,775	744	1,512
Arkansas	2,306	433	883	911	—	401
Georgia	1,119	714	1,363	1,253	832	995
Louisiana	1,604	1,472	—	2,510	—	—
Mississippi	3,231	1,581	3,871	2,419	—	—
North Carolina	523	477	798	701	695	406
South Carolina	2,056	660	1,356	1,341	—	371
Tennessee	648	800	749	934	—	387
Virginia	—	1,101	—	1,228	—	458
Southeast	1,814	980	1,327	1,320	884	615

— = Too few observations for a reliable estimate.

Source: (*18, 19*).

Table 18—Regression results for the relationship of farm size and double-cropping[1]

Year	Parameter	Least-squares estimate	|T| value	Regression F-value
1978[2]	b_1	0.03598	4.45*	9.89
	b_2	−.00108	3.70***	
1982	b_1	.45404	14.76***	125.66
	b_2	−.09749	10.08***	

* = statistically significant at the 10-percent confidence level.
*** = statistically significant at the 1-percent confidence level.

[1]Model: % soybean acres double-cropped − b_1 (total crop acres/1000) + b_2 (total crop acres/1000)^2 + E.
In 1978, there were three unusually large total crop acres reported between 15,000 acres and 40,000 acres (these observations influenced the slope and curvature of the regression line and may have caused some distortion.)

[2]"Total crop acres" was divided by 1,000 to obtain more precision in the parameter estimates and standard errors.

reduction in support prices for all currently supported commodities. The decision model discussed earlier does not explicitly include provisions for policy change, but it may give a basis from which to begin the discussion. If the support price for wheat had been reduced by 10 percent in 1984, it would have affected several factors in the decision model. First, the expected total revenue from wheat would probably have been lower since the reduction in the support price would have driven down the wheat futures price. Also, the variance of total revenue for wheat would increase since there would be more room for downward movement in the price received by the producer. This would also affect the covariance of returns between soybeans and wheat, assuming the price of soybeans is unaffected by the changing price structures of other commodities. From the effect of a change in the wheat support price alone on the above factors, the model predictions for 1984 indicate that the proportion of double-cropped soybean acreage in the Southeast would have declined by about 20 percent on average. It is clear, however, that several factors cannot be taken into account within the framework of this model.

The first important factor left out is that a reduction in the commodity program for wheat would surely not be made in isolation. If all support prices were reduced, the effect on double-cropping is uncertain. Corn, for example, is a competing crop for soybean land in most of the Southeast. Farmers are interested in increasing profit and reducing relative risks, but these interests are usually competing. If the general increase in uncertainty associated with all commodities causes farmers to be more conservative in their planning, Southeastern soybean producers may turn to increased full-season soybean production because this practice is less risky. On the other hand, the expected general profitability of traditional agricultural production may decline and provide incentive for more intensive production, (like double-cropping), thereby allowing farmers to gain the most return per unit of fixed resources such as land and management. It is difficult to tell which effect would dominate. Some farmers will have to produce more intensively in order to survive at lower commodity prices. Of course, the overall survival rate would affect the future levels of commodity prices in general as well.

Another important factor omitted is the possible movement of commodity prices toward world market prices and, therefore, increased quantities of wheat and other grains demanded for export. This may provide incentive for increased wheat production relative to soybean production since the support price on soybeans has not generally been binding. Also, as U.S. commodity prices fall toward and become more related to world prices, they may become more stable since any U.S. supply shock would generally be distributed over all the producing countries and each shock should affect the price to a lesser degree than is now the case. The efficient producers who survive at world prices may see a reduction in commodity price risk.

Other factors could affect the future of double-cropping, some of a political nature and some of a more technical nature. There are also feedback, or second-round, effects of any changes, such as increased wheat production depressing wheat prices further, falling land prices from lower commodity prices, or increased soybean production creating supply pressure on soybean prices. We feel that double-cropping will provide an opportunity for greater relative profitability on farms where the growing season is sufficient and where management skills are appropriate. Even under the restructured agricultural programs, as more producers learn how to manage the technology, the acreage devoted to double-cropping will probably continue to increase.

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Appendix:

The Modeling Process for Analysis of Double-Cropping Patterns Over Time

An individual's utility of profit is defined as:

$$U(\pi) = U[(\propto P_sBX + rP_wWX + P_sB(1-X) - C(X))L], \quad \text{(App. 1)}$$

where:

$U(\pi)$ = utility of profit from the soybean acreage,

$\propto$ = the percentage of double-cropped soybean yield relative to full-season soybean yield, $0 < \propto \leqslant 1$,

P_s = the uncertain market price of soybeans per bushel,

B = the uncertain yield of full-season soybeans in bushels per acre,

X = the fraction of total soybean acreage double-cropped,

r = 1 + the opportunity interest rate on operating capital,

P_w = the uncertain market price of wheat per bushel,

W = the uncertain yield of wheat in bushels per acre,

C(X) = the total cost of production per acre for the soybean acreage including both the single- and double-cropped acreage, and

L = the total acreage planned to be either single- or double-cropped.

The opportunity interest rate on operating capital is implicitly included in two terms in equation app. 1. It is a component of total cost, C(X), and of the revenue from the wheat crop, rP_wW. In a double-cropped system, the producer must borrow operating capital earlier in the growing season to be able to plant the wheat crop, but he also has the opportunity to use the mid-period income from that crop to invest or to defray soybean production costs. There is some indication that this mid-period income is attractive to producers and may provide some incentive to double-crop. Theory suggests, however, that fairly well-functioning capital markets would make the timing of income a matter of relative indifference.

We specify production cost as total cost for the entire soybean acreage and do not specify separate cost functions for the two systems or for the two crops. A more complex cost structure may exist, but in this case we are unable to observe the cost functions in as much detail as the revenue functions. We assume the marginal cost is proportional to X to allow for the ability to allocate inputs differently over time and space with increased double-cropped acreage. Since we assume costs are nonstochastic, the simple specification is all that is needed for the current analysis.

Equation app. 1 is a function of two random variables, P_sB and P_wW. The producer maximizes the expected utility of profit, $EU(\pi)$, with respect to the proportion of total soybean acreage double-cropped, X. The first-order condition for a maximum, FOC, can be written (with ′ denoting derivatives) as:

$$FOC = \partial EU(\pi)/\partial X = \{E\ U'(\pi)[(\propto P_sB + rP_wW - P_sB - C'X)L]\} = 0. \quad \text{(App. 2)}$$

The change in the expected utility of profit from a one-unit change in the double-cropped proportion, X, is the additional revenue from the double-cropped acreage minus the foregone revenue from the single-cropped acreage less the net addition to total cost from the increase in double-cropped acreage.

Taking the expectations operator, E, through equation app. 2 and combining terms gives:

$$EU'(\pi)\ [(\propto - 1)E(P_sB) + rE(P_wW) - C'X]L + (\propto - 1)L\mathrm{cov}(U'(\pi)P_sB) + rL\mathrm{cov}(U'(\pi),P_wW) = 0.$$

Dividing through by L and applying Stein's Theorem (*17*) to $\mathrm{cov}(U'(\pi),P_sB)$ and $\mathrm{cov}(U'(\pi),P_wW)$ gives:

$$\begin{aligned} &EU'(\pi)(\propto - 1)E(P_sB) + EU'(\pi)rE(P_wW) \\ &\quad - EU'(\pi)C'X \\ &+ (\propto - 1)EU''(\pi)\ \{(\propto X - X + 1)L\mathrm{var}(P_sB) \\ &\quad + rXL\mathrm{cov}(P_sB,P_wW)\} \\ &+ rEU''(\pi)\ \{(\propto X - X + 1)L\mathrm{cov}(P_sB,P_wW) \\ &\quad + rXL\mathrm{var}(P_wW)\} = 0. \end{aligned} \quad \text{(App. 4)}$$

The next task is to develop a statistical model suitable for use in empirical applications. Solving equation App. 4 for X and rearranging it in terms of the unknowns, $EU'(\pi)$ and $EU''(\pi)$, gives:

$$X^* = [EU'(\pi)X_1 + EU''(\pi)X_2]/[EU'(\pi)X_3 + EU''(\pi)X_4] \quad \text{(App. 5)}$$

where:

X^* = the optimal proportion of soybean acreage double-cropped,

$X_1 = (\propto - 1)E(P_sB) - rE(P_wW)$,

$X_2 = (\propto - 1)L\mathrm{var}(P_sB) - Lr\mathrm{cov}(P_sB,P_wW)$,

$X_3 = -C'$, and

$X_4 = (\propto - 1)^2L\mathrm{var}(P_sB) + r^2L\mathrm{var}(P_wW)$ $[2(\propto - 1)]rL\mathrm{cov}(P_s,P_wW)$.

The resulting econometric model is:

$$X^* = b_0 + (b_1X_1 + b_2X_2)/(b_3X_3 + b_4X_4) + e. \quad \text{(App. 6)}$$

An intercept term was added to the theoretical derivation to take into account locational differences and to expedite global minimization in the nonlinear regression algorithm SAS NLIN. The error term, e, is assumed to have an expected value of zero and takes into account factors known to decisionmakers but not observable by the authors. Note that, since State-level data were used for estimation, the parameter pairs b_1, b_3 and b_2, b_4 were not set equal because they contain unknown aggregation function parameters as well as the utility function parameters. If individual farm data were available, this model could be used to estimate the expected values of the derivatives of the utility function and thus provide some evidence on risk attitudes from real-world decisionmaking.

Readings On

Soil Conservation and Farmland

Assessing Erosion on U.S. Cropland: Land Management and Physical Features, by Nelson L. Bills and Ralph E. Heimlich. AER-513. July 1984. 24 pp. $1.50. Order SN: 001-019-00341-3 from GPO.

Erosion from rainfall causes nearly 100 million acres of U.S. cropland to erode by more than 5 tons per acre per year. One-third of this land is so highly erosive that annual soil loss can be reduced to tolerable levels only under the most restrictive land management practices. More than one-third of U.S. cropland is inherently nonerosive under all management regimes, about half requires conservation management to keep soil loss within tolerable limits, and the remaining 8 percent is so erosive that acceptable soil loss rates cannot be achieved under intensive cultivation.

Do USDA Farm Program Participants Contribute to Soil Erosion? by Katherine H. Reichelderfer. AER-532. April 1985. 84 pp. $3.00. Order SN: 001-019-00383-9 from GPO.

Finds that only about one-third of U.S. cropland with excessive soil erosion rates is operated by farmers who might be influenced to reduce erosion if changes were made in USDA's commodity and soil conservation programs. Present commodity programs may conflict with conservation programs by encouraging cultivation of erosive crops. Efforts to increase the consistency of USDA commodity and conservation programs would contribute little to overcoming the Nation's total erosion problem.

Cropland Rental and Soil Conservation in the United States, by Nelson L. Bills. AER-529. March 1985. 20 pp. $1.50. Order SN: 001-019-00387-1 from GPO.

Data from USDA's Resource Economics Survey challenge the common but not well-substantiated view that farmers are less concerned with erosion on land they rent than on land they own. At the national level, farmers' conservation efforts on rented cropland compare favorably with those on owner-operated cropland.

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Agriculture's Links With U.S. and World Economies, by Alden C. Manchester. AIB-496. September 1985. 60 pp. $1.50. Order SN: 001-019-00409-6 from GPO.

Describes the linkages between farming and the supplying industries and those manufacturing and distributing farm products. Within the last 30 years, the food and fiber system has found itself increasingly reliant on nonfarm industries and increasingly affected by general economic developments, not only within the Nation but from overseas as well.

Improving U.S. Farmland, by Douglas Lewis and Thomas A. McDonald. AIB-482. November 1984. 12 pp. $1.00. Order SN: 001-019-00362-6 from GPO.

A clear, concise account of recent farmland improvements. Farmers invested more than $6.5 billion in improving their land in a recent 3-year period. Those investments, while often made on existing cropland, expanded total U.S. cropland by 9.1 million acres.

Major Uses of Land in the United States: 1982, by H. Thomas Frey and Roger W. Hexem. AER-535. June 1985. 36 pp. $1.25. Order SN: 001-019-00398-7 from GPO.

Discusses the major uses of the Nation's 2,265 million acres of land in 1982: cropland, 469 million acres; grassland pasture and range, 597 million acres; forest land (exclusive of areas in special-purpose uses), 655 million acres; special uses, 270 million acres; and miscellaneous other land, 274 million acres. Changes in cropland and pasture acreages were barely perceptible during 1978-82; forest land (except special use areas) and miscellaneous other land decreased sharply as large acreages in these categories were reclassified as parks, wilderness, and related uses.

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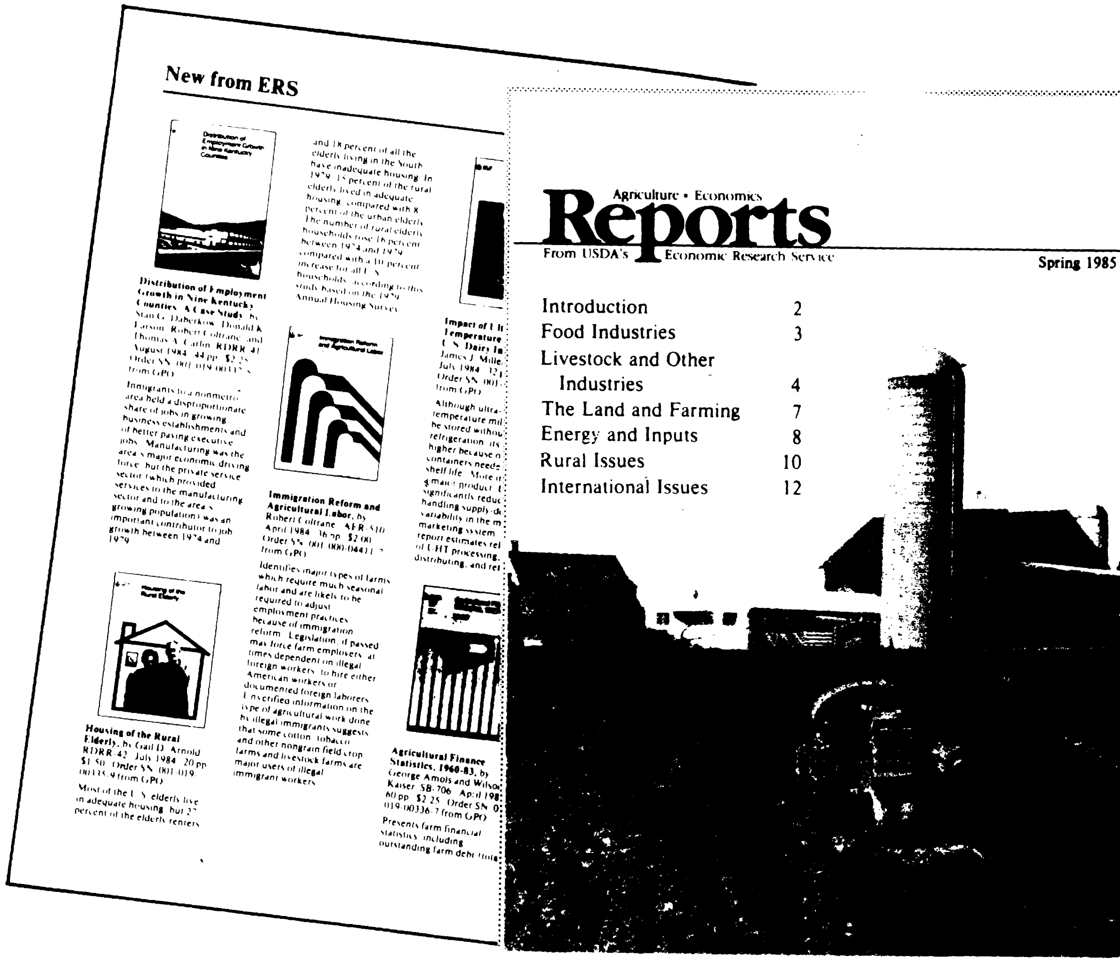
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